

NO_x Heavy-Duty Defeat Device Modeling for MOBILE6

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US EPA Office of Mobile Sources

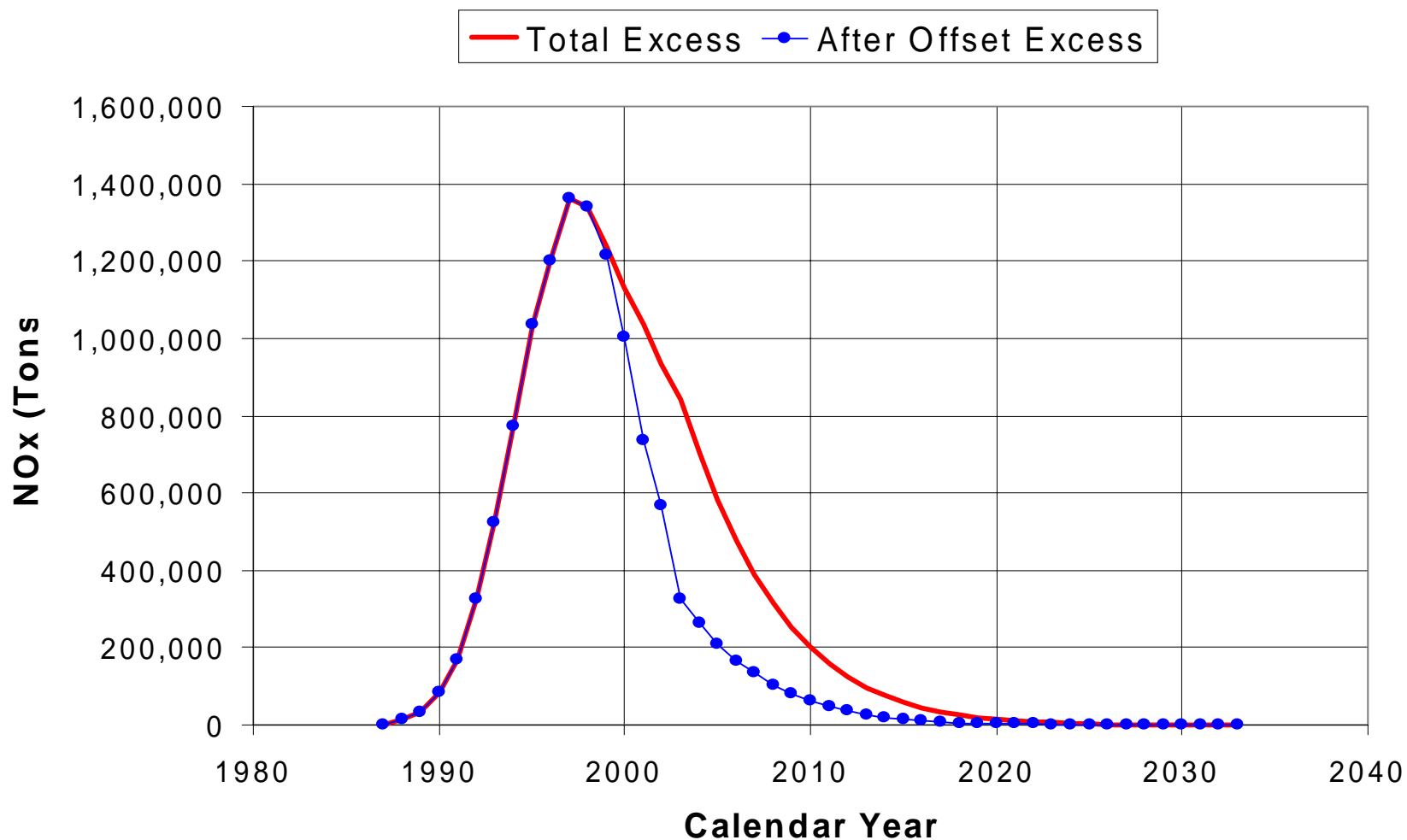
Overview of Presentation

- What are Defeat Devices?
- OECA Modeling Approach
- Modified MOBILE5b V2.0 Modeling Approach
- Potential Bottom Up Approach Used for Tier2
- What to do for MOBILE6 ?

OECA Modeling

- OECA Model was developed in conjunction with the EPA / Manufacturer Consent Decree.
- It is based on limited test data and engineering judgement.
- It predicts Total NO_x Excess Emissions by Calendar Year Only.
- Mitigation effects due to rebuilding of engines, pull ahead of certification requirements and control of non-road engines are subtracted from the total to produce a net effect.

Excess NOx Emission Levels Due to the HD Defeat Device and Mitigation Strategies (Offsets)



Assumptions for Offset Calculations

- **Rebuild Program**

- Rebuild Rate 90%
- Rebuild Mileage Line Hauls 350,000
- Rebuild Mileage Non Line Hauls 300,000
- Rebuild Level 7 g/bhp-hr
- Covered Engines 1994-98 MY

- **2 gram Pull Ahead** (Early Introduction of Tighter Stds)

- Emission Level After Pull Ahead 1.84 g/bhp-hr
- Maintains 1998 Production Levels

- **Small Non Road Engine Pull Ahead** (small benefit)

- Applied to engines 300 to 750 HP
- Based on Industry Data

Modified MOBILE5b V2.0

Modeling Approach

- Begin with OECA Excess NOx Emission Values in Tons per Calendar Year
- For Each Calendar Year, Divide OECA Tons by Total Heavy-duty VMT. This will produce a gram per mile NOx Excess Emission Factor.
- Add the NOx Excess Emission Factor to the MOBILE5b NOx Emission Factor for the Affected Calendar Years (1988 through 2033).

Defeat Device NOx Emission

Summary for MOBILE5B V2.0

Calendar Year	MOBILE5 BASE (g/mi)	Defeat Device Total (g/mi)	Net After Offset (g/mi)	Total Increase (g/mi)	Net Increase (g/mi)	Total Increase (%)	Net Increase (%)
1990	21.74	22.63	22.63	0.89	0.89	4.1	4.1
1995	15.28	23.60	23.60	8.32	8.32	54.5	54.5
2000	11.58	18.89	18.06	7.31	6.48	63.1	56.0
2005	8.98	12.17	10.12	3.19	1.14	35.5	12.7
2010	8.00	8.96	8.30	0.96	0.30	12.0	3.8
2015	7.63	7.88	7.69	0.25	0.06	3.3	0.8
2020	7.57	7.63	7.57	0.06	0.00	0.8	0.0
2025	7.55	7.56	7.55	0.01	0.00	0.1	0.0

Issues with the Modified MOBILE5B V2 Approach

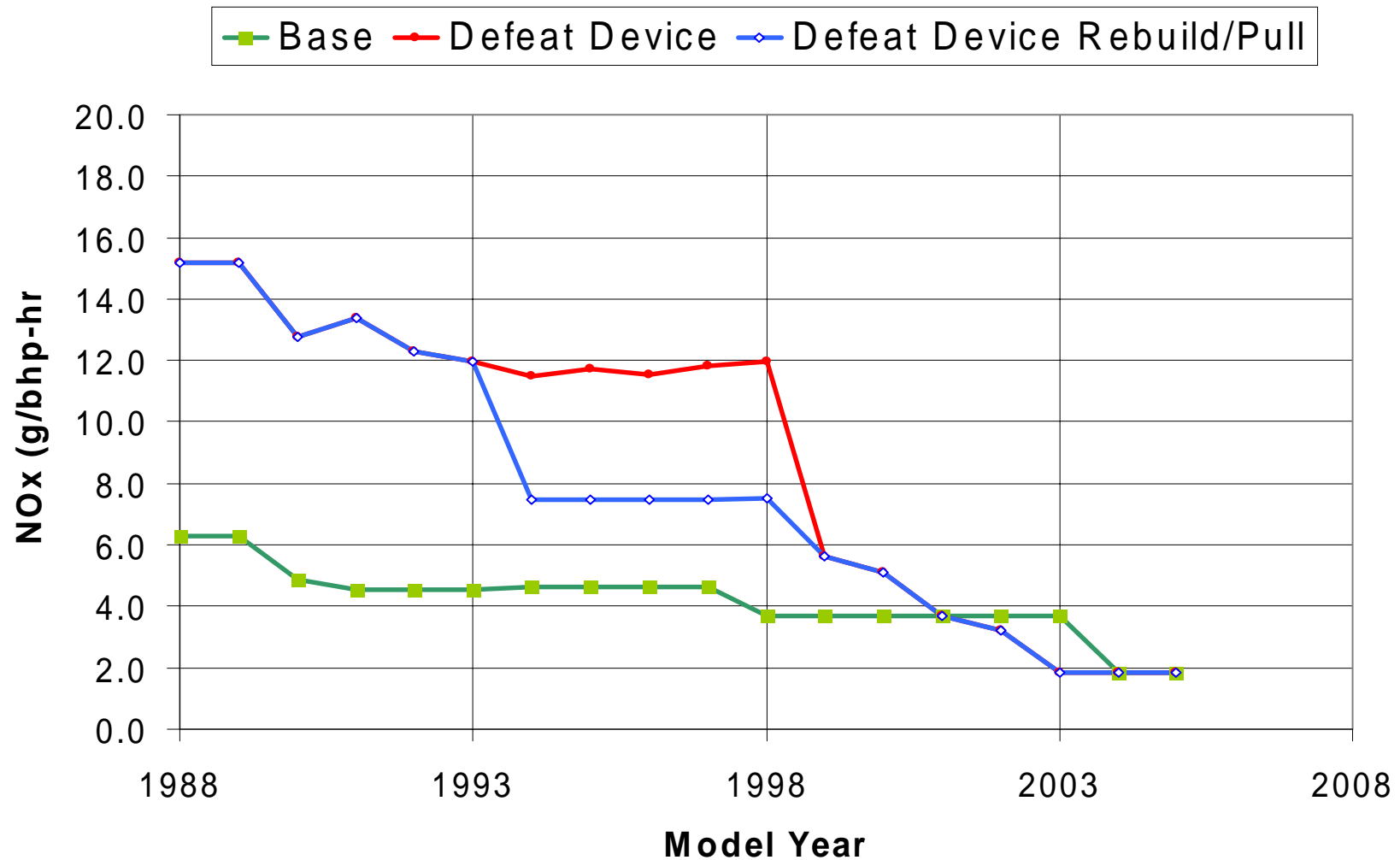
- Positives
 - Matches OECA Inventories and Projections
 - Easily Accounts for Rebuilds and Pull-ahead
 - Easily Understood and Programmed
- Shortcomings
 - Calendar Year Only Basis
 - Cannot Account for by model year variances, roadway influences, or speed effects
 - Unknown Data Sources

Proposed Tier2 Approach

- NOx Emission Factors
 - Base NOx Emission Levels Without Defeat Device Effects
 - Default MOBILE6 Values
 - 8 percent Compliance Margin
 - With Defeat Device NOx Emission Levels
 - Obtained from the Same Sources as the OECA Model - Based on Limited Test Data and Engineering Judgement.
 - Sales Weighted by Manufacturer

8b HDDV NO_x Emission Factors

Average NO_x Emission Factors for an 8b Diesel Vehicle

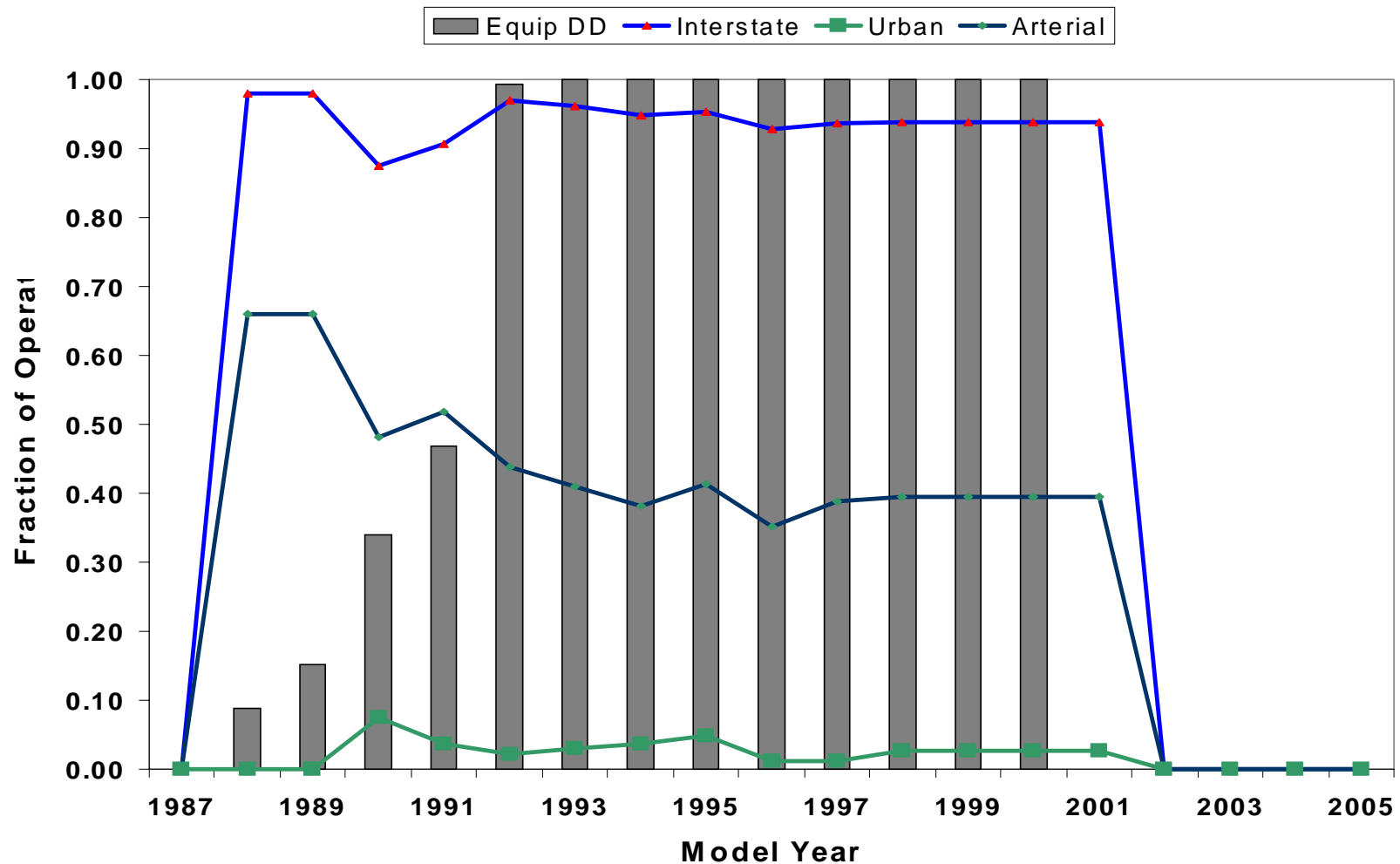


Tier2 Approach (Con't)

- **Defeat Device Activity Data by Roadway Type**
 - Three Roadway Types (Interstate, Arterial and Urban)
 - Based on Limited Test Data and Engineering Judgements.
 - Sales Weighted by Manufacturer

8b HDDV Defeat Device Activity Parameters

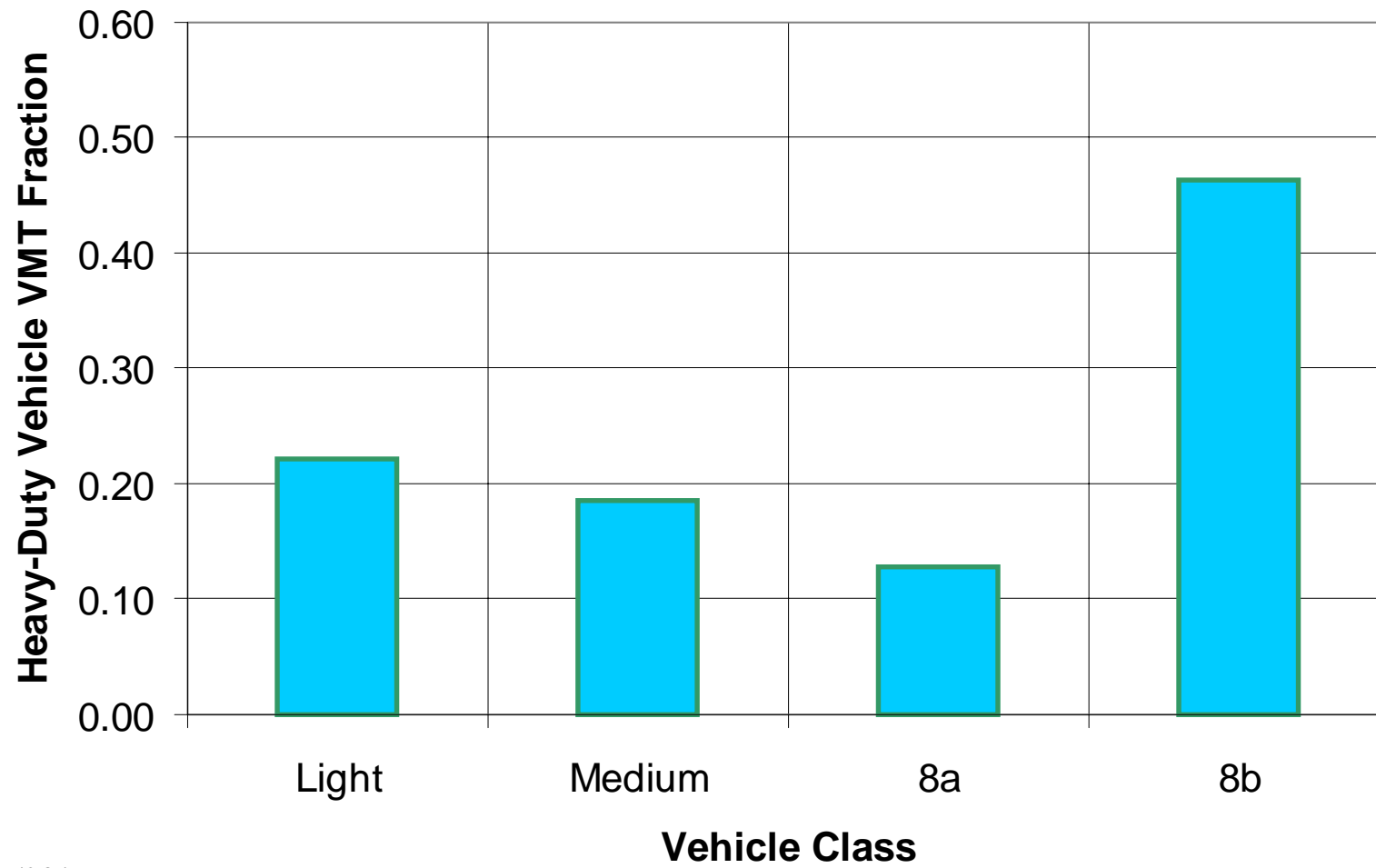
Fraction of Defeat Device Operation by Mode



VMT Distributions

- Distribution by Vehicle Class (Light, Medium, 8a and 8b heavy duty)
- Distribution by Roadway Type (Urban, Arterial and Interstate)
- Distribution by Model Year / Age
- Total VMT by Calendar Year

Heavy-Duty Vehicle VMT Distribution by Weight Class

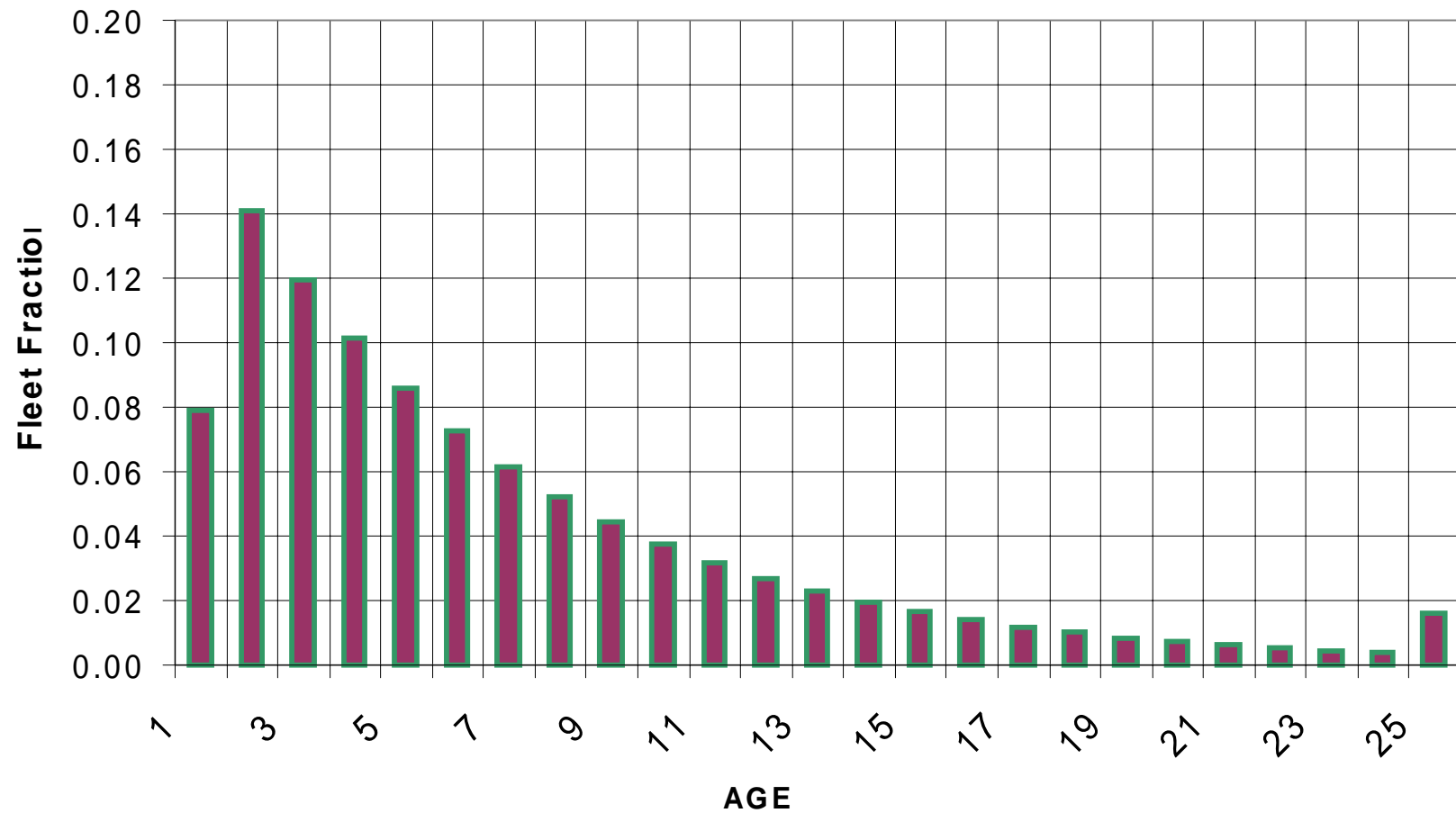


VMT Distribution by Roadway Type

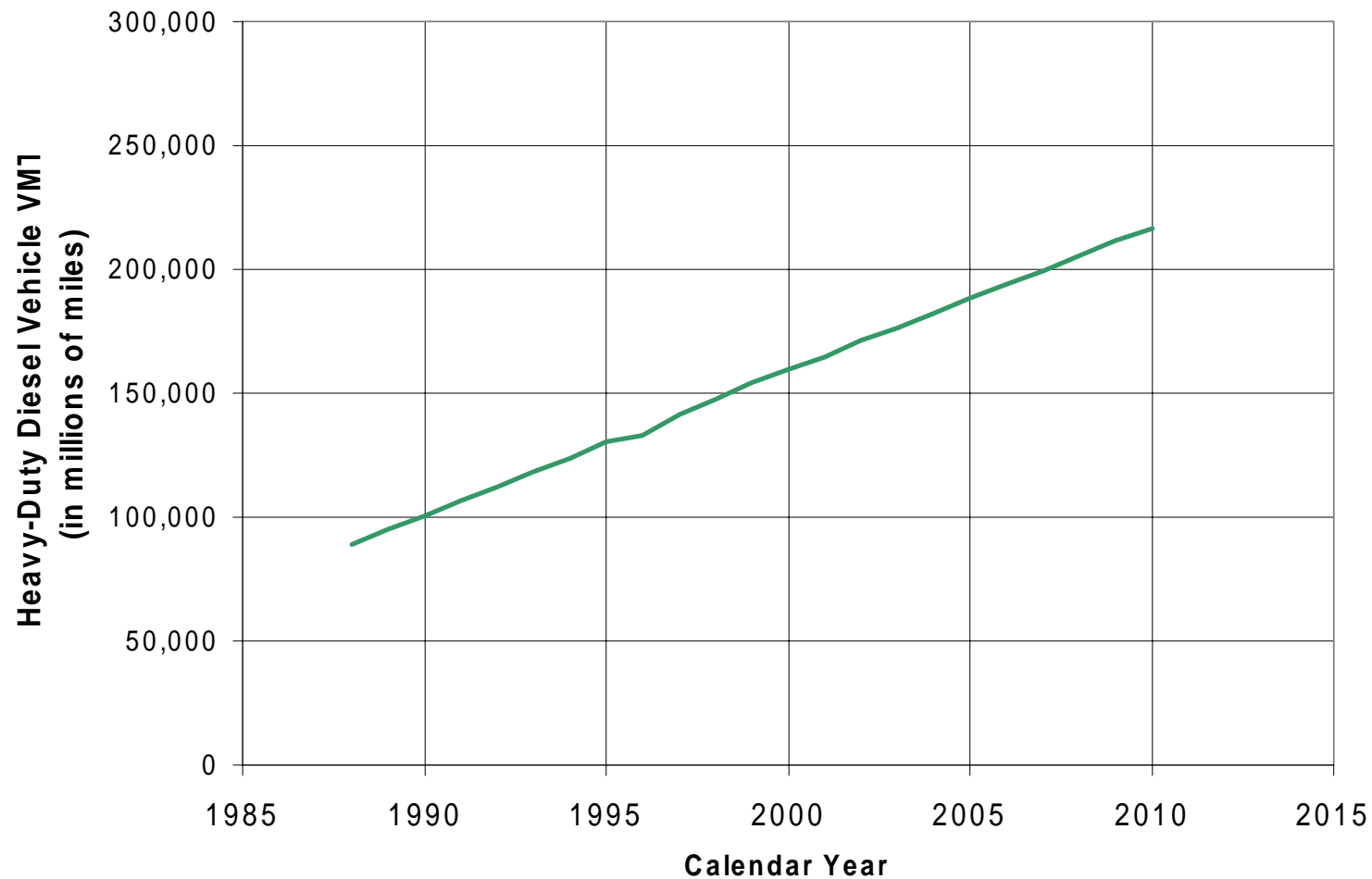
<u>Road Description</u>	<u>Light</u>	<u>Medium</u>	<u>8a</u>	<u>8b</u>
Rural Interstate	15.3	8.8	19.9	26.5
Rural Other Prin Arterial	14.8	8.5	19.2	25.6
Urban Interstate	8.5	5.2	11.9	15.8
Urban Other Freeways	4.0	2.3	5.3	7.0
Rural Minor Arterial	10.2	7.4	4.4	4.1
Rural Major Collector	12.5	9.0	5.3	5.0
Rural Minor Collector	3.4	2.4	1.4	1.3
Rural Local	6.8	5.1	3.0	2.8
Urban Other Prin Arterial	9.1	19.1	11.0	4.4
Urban Minor Arterial	7.4	15.1	8.7	3.5
Urban Collector	2.8	6.5	3.8	1.5
Urban Local	5.1	10.6	6.1	2.5

VMT Distribution by Age

(MOBILE6)



Heavy-Duty Diesel Vehicle Total VMT from EPA Trends Report



Other Factors

- Heavy-duty Vehicle “Units” Conversion Factors
- Speed Correction Factors (Not Applied to Defeat Device Effects)
- Defeat Device Mitigation Effects
 - Modeling Pull Ahead (Early introduction of tighter certification standards and Use of Not to Exceed Standards)
 - Effects of the Rebuild program
 - Plan A
 - Plan B

Final Result

- Compute a Series of Ratios
 - Fleet Average Defeat Device Emissions Over Fleet Average Without Defeat Device Emissions
 - Ratio is a Function of:
 - Model Year
 - Vehicle Class
 - Roadway Type
 - Apply Ratios to Base MOBILE6 Heavy-Duty NOx Emission Factors

No Defeat Device Calculations

Results Ratio Denominator

- $\text{NODDE}(\text{spd}, \text{icls}, \text{my}) = \text{NODDBEF}(\text{my}) * \text{CF}(\text{icls}, \text{my}) * \text{SpdCF}(\text{spd})$

- $\text{NDD}(\text{spd}, \text{road}) = \text{SUM}(\text{icls}) \text{SUM}(\text{my}) \{ [\text{NODDE}(\text{spd}, \text{road}, \text{my}, \text{icls}) * \text{TF}] * \text{wgtcls}(\text{icls}) \}$

- NODDBEF is the basic NOX emission level
- CF is the conversion factor
- SpdCF is the M5 speed correction factor
- TF is the M5 travel fraction
- Wgtcls is the VMT weighting between weight classes
- “icls” are the four heavy-duty vehicle weight classes
- “road” are the twelve roadway types

Defeat Device Calculations

Results Ratio Numerator (for each Roadway Type)

- $$\text{DDE}(\text{spd}, \text{icls}, \text{my}) = \text{NODDBEF}(\text{my}) * (1 - \% \text{Fleet}(\text{my}, \text{icls})) * \text{SpdCF}(\text{spd}) +$$
$$\text{NODDBEF}(\text{my}) * (\% \text{Fleet}(\text{my}, \text{icls}) * (1 - \% \text{mode}(\text{my}, \text{icls})) * \text{SpdCF}(\text{spd}) +$$
$$\text{DDBEF}(\text{my}) * \% \text{Fleet}(\text{my}, \text{icls}) * \% \text{mode}(\text{my}, \text{icls})$$
- $$\text{DD}(\text{spd}, \text{icls}) = \text{SUM}(\text{icls}) \text{SUM}(\text{my}) \{ [\text{DDE}(\text{spd}, \text{road}, \text{my}, \text{icls}) * \text{TF}] * \text{wgtcls}(\text{icls}) \}$$
 - NODDBEF is the basic NOX emission level without defeat devices.
 - DDBEF is the basic NOX emission level with defeat devices present.
 - %Fleet is the fraction of the fleet equipped with defeat devices.
 - %Mode is the fraction of time a vehicle spends in defeat device mode.

Issues

- Heavy-duty Diesel NO_x Excess Calculations in MOBILE6 are still at the Blank Piece of Paper Stage. - **Now is the time to Comment!**
- Are the OECA Inventories Reasonable? If not Why?
- Are There Any New Data with which to Evaluate the NO_x Excess Emission Levels or Activity Levels?